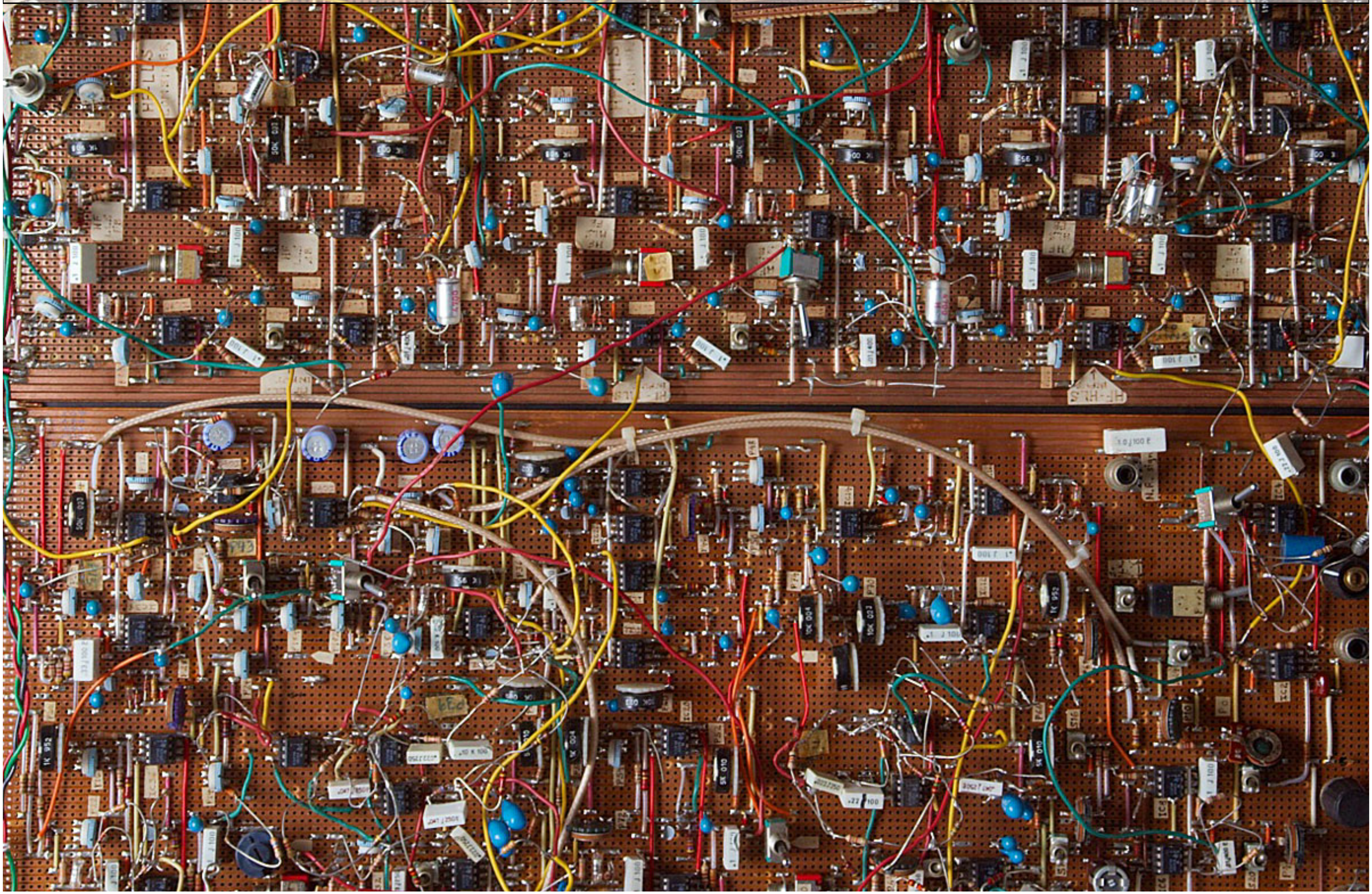
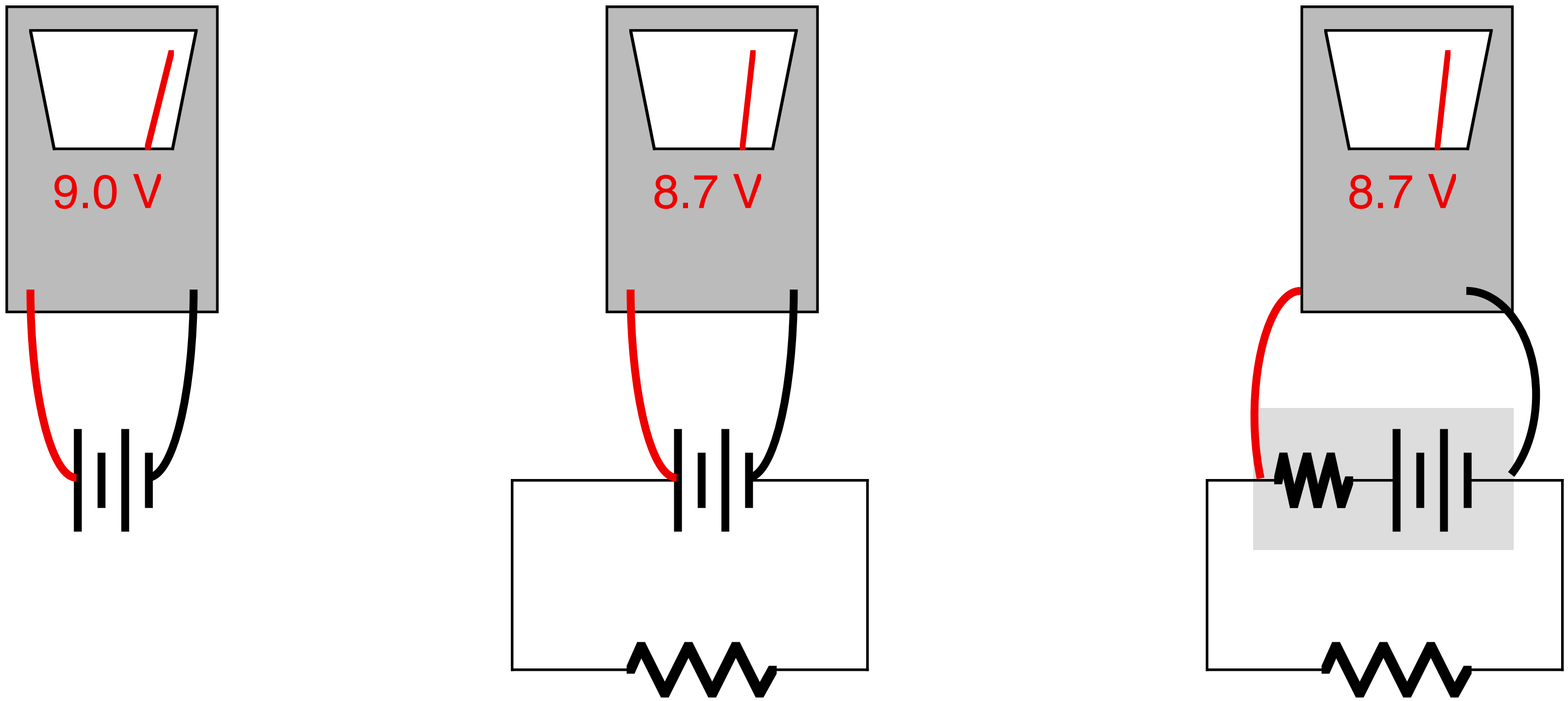
Ch 28-DC Circuits



EMF & Terminal Voltage



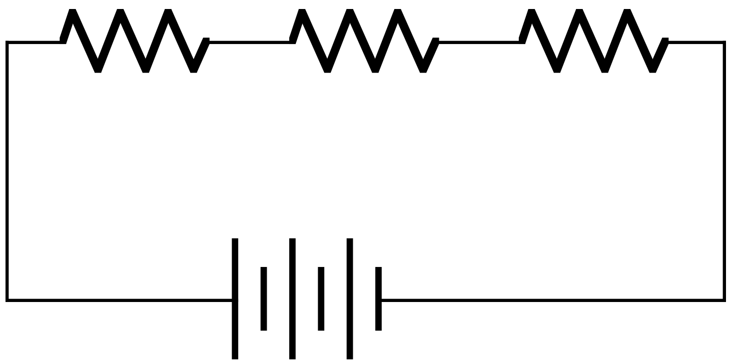
$$V = \mathcal{E} - Ir$$

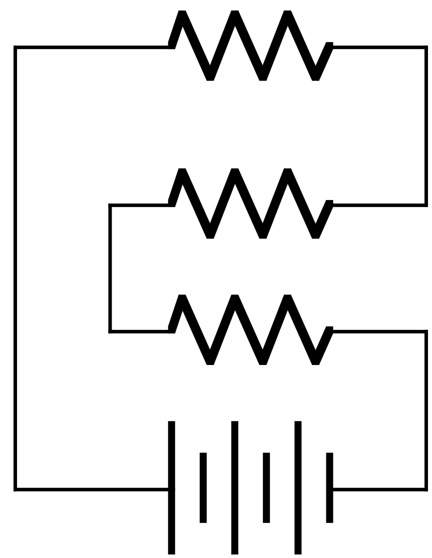
Terminal voltage

Open circuit voltage (emf)

internal resistance

Resistors in series

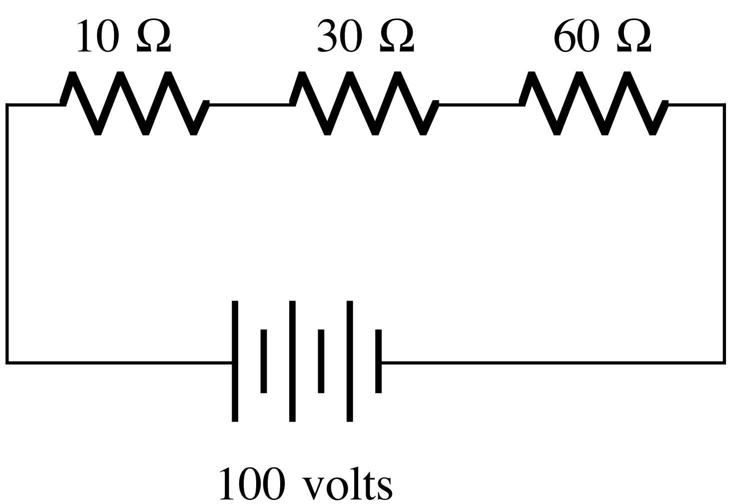




Resistors in series

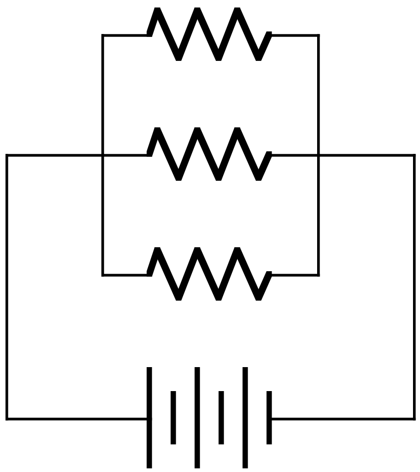
What is the current flow in this model?
What is the voltage drop across each resistor?

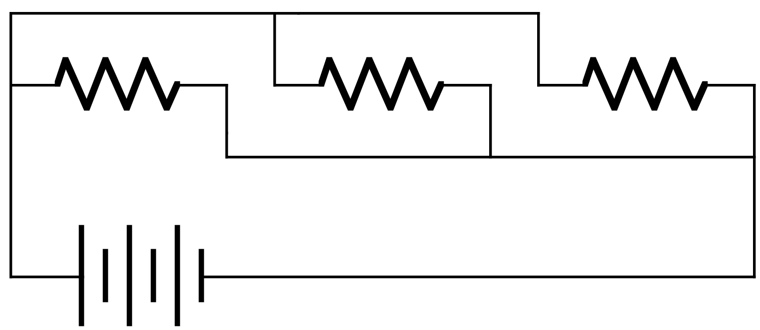
(Look at "series movie" in "Richard's stuff")



$$R_{equivalent} = R_1 + R_2 + R_3 + \ldots \text{(for resistors in series)}$$

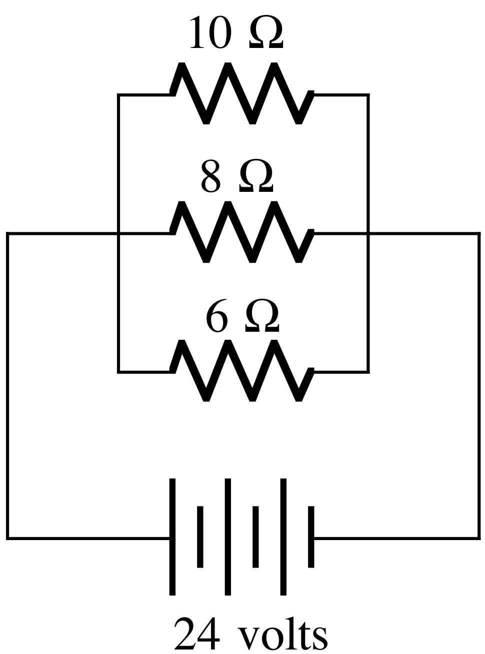
Resistors in parallel





Resistors in parallel

What is the voltage drop over each resistor in this model?
What is the current through each resistor?

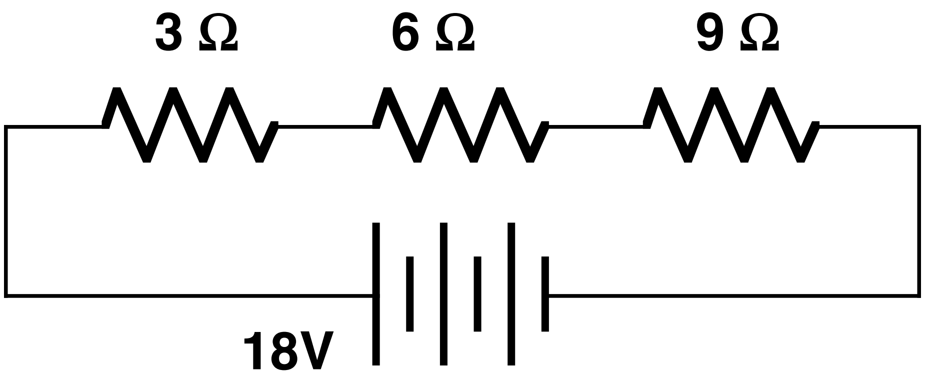


(Look at “parallel movie” in “Richard’s stuff”)

$$\frac{1}{R_{equivalent}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \text{ (for resistors in parallel)}$$

Example 1

Examine the circuit here.



a. What is the equivalent resistance?

R_{equiv}=3W+6W+9W=18W

b. Find the current flowing throughout the circuit.

I=V/R=18V/18W =1.0A

c. What is the potential at every point in the circuit.

V_3=IR=(1A)(3W)=3V; V_6=6V; V_9=9V

d. What is the Power delivered by the battery?

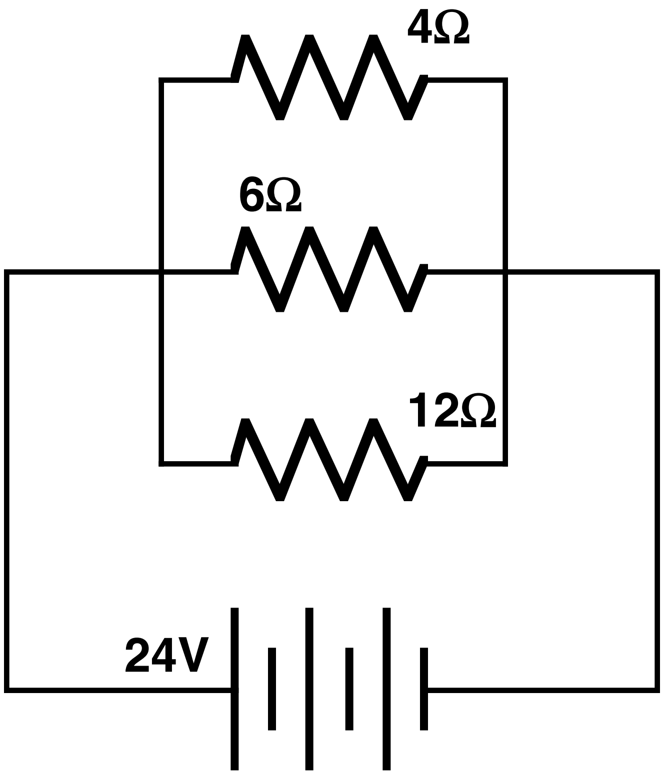
P=IV=(1.0A)(18V)=18W

e. What is the Power consumed by each resistor?

P_3=IV=(1.0A)(3V)=3W; or use $P_3=I^2R$=(1A)(3W)=3W; or use $P_3=V^2/R=(3V)^2/3A$=3W; P_6=6W; P_9=9W

Example 2

Examine the circuit here.



a. What is the equivalent resistance?

$1/R_{equiv}=1/4W+1/6W+1/12W$; $R_{equiv}=2W$

b. Find the current flowing throughout the circuit.

V drop identical for each resistor=24V

c. What is the potential at every point in the circuit.

I from battery = V/R_{equiv} = 24V/2W =12A;

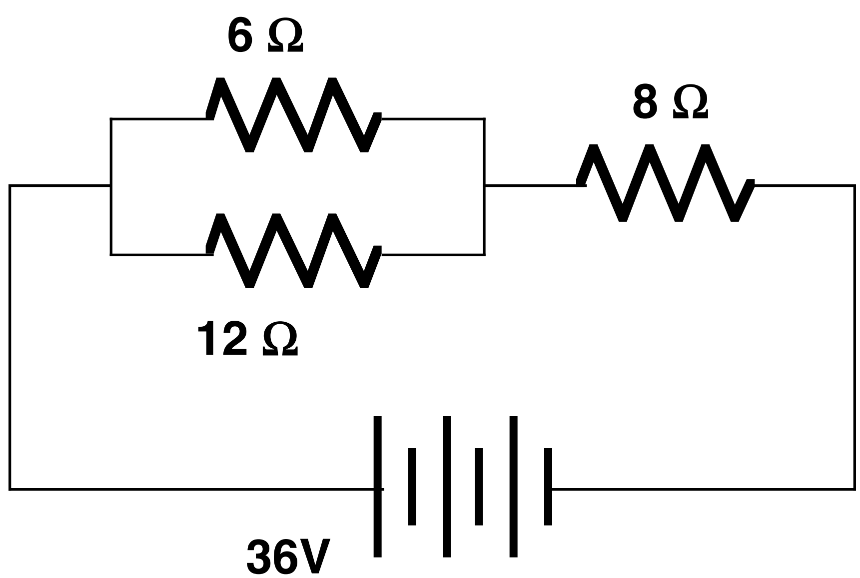
$I_4=V/R=(24V)/(4W)=6A$; $I_6=4A$; $I_{12}=2A$

d. What is the Power delivered by the battery?

e. What is the Power consumed by each resistor?

Example 3

Examine the circuit here.



a. What is the equivalent resistance?

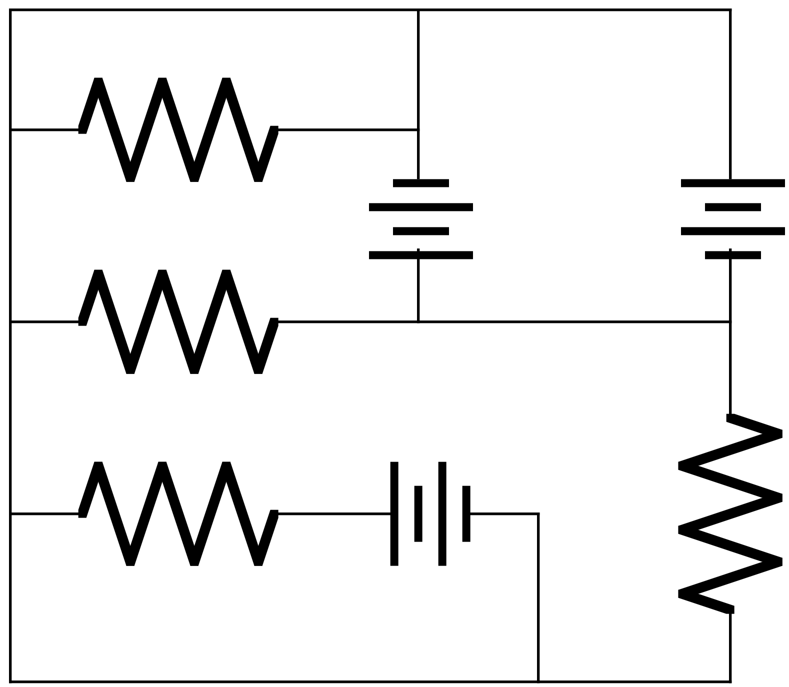
b. Find the current flowing throughout the circuit.

c. What is the potential at every point in the circuit.

d. What is the Power delivered by the battery?

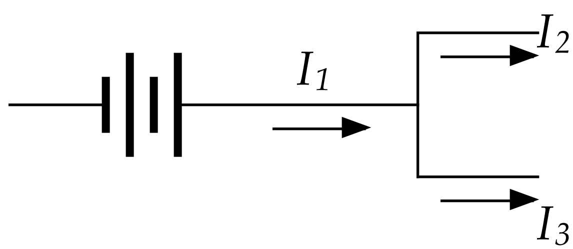
e. What is the Power consumed by each resistor?

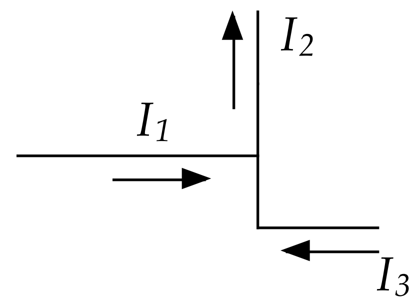
Kirchhoff’s Rules

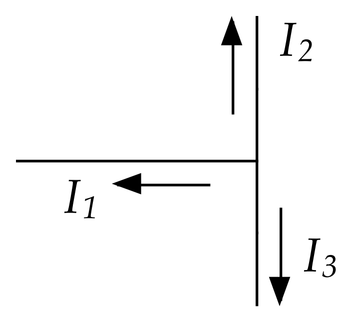


Kirchhoff's Rule 1

"The Junction Rule" - Total current into a node = total current out of a node

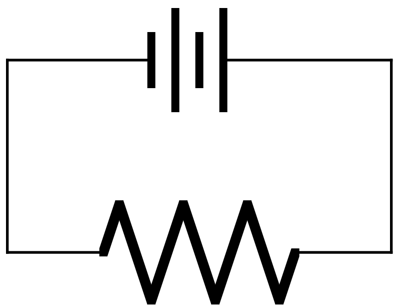


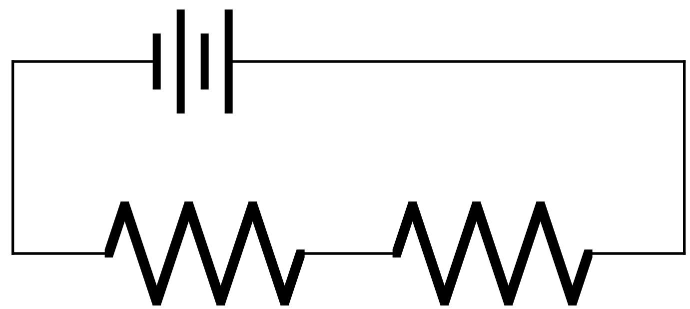


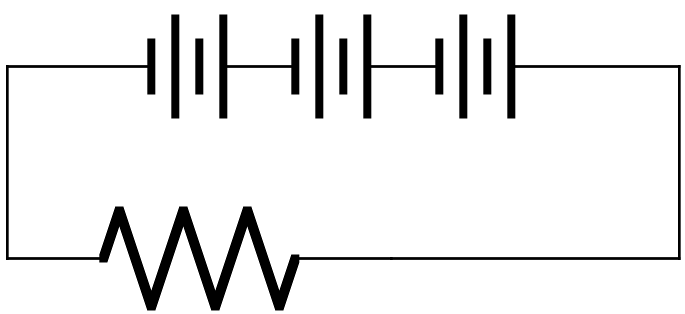


Kirchhoff's Rule 2

"The Loop Rule" - The sum of the potential changes around a closed loop must equal zero.





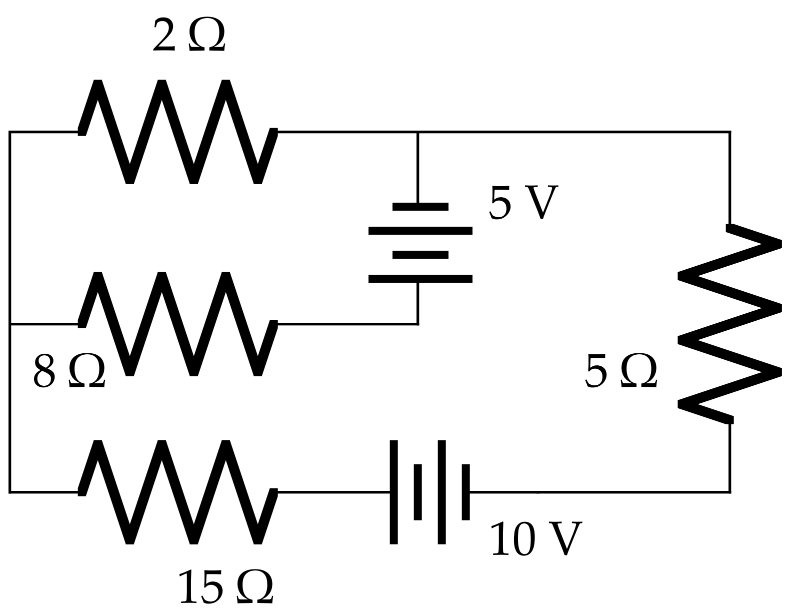


Using Kirchhoff' s

1. On circuit diagram, identify and label a current and direction of flow for each separate branch of the circuit.
2. Write out a series of Node equations using Kirchhoff' s Junction Rule.(Make sure you don' t duplicate any equations!)
3. Write out a series of Loop equations using Kirchhoff' s Loop Rule. (The total number of Junction and Loop equations = the number of unknown currents you' re solving for.)
4. Solve these simultaneous equations.

Example 4

Examine the circuit here.



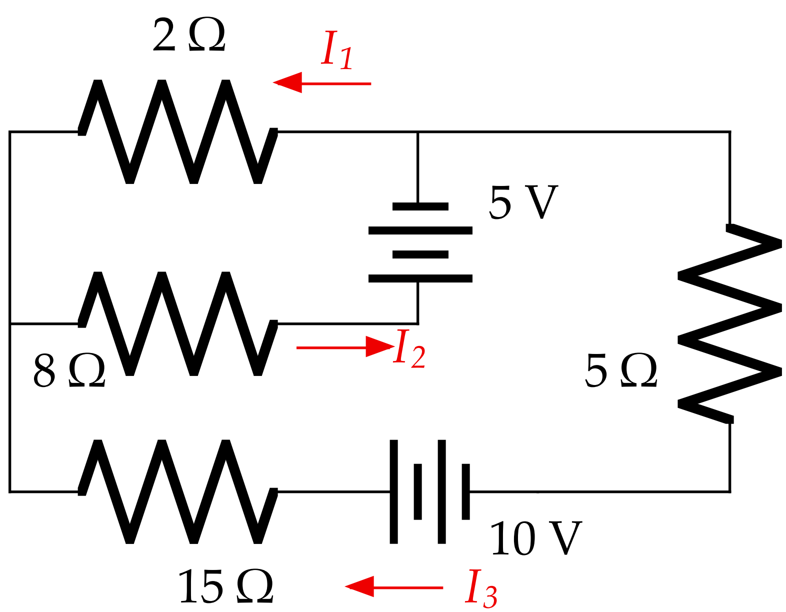
a. What is the current flow, everywhere?

b. What are the voltages, everywhere?

c. What is the Power consumed/produced, everywhere?

Example 4

Examine the circuit here.



Apply Kirchoff' s rules to circuit with currents (arbitrarily chosen here) to get:

$$I_1 + I_3 = I_2$$

$$10 - 15I_3 - 8I_2 - 5 - 5I_3 = 0$$

$$5 + 8I_2 + 2I_1 = 0$$

Example 4

$$I_1 - I_2 + I_3 = 0$$
$$0I_1 - 8I_2 - 20I_3 = -5$$
$$2I_1 + 8I_2 + 0I_3 = -5$$

$$\begin{matrix} 1 & -1 & 1 & 0 \\ 0 & -8 & -20 & -5 \\ 2 & 8 & 0 & -5 \end{matrix}$$

a. Math -> Matrix -> Edit -> A (for name of matrix)

b. 3 [Enter] 4 [Enter]

c. Enter coefficients and values into Matrix

d. Do "rref" A (reduced row echelon form)

e. Interpret answers from matrix

$$\begin{bmatrix} 1 & -1 & 1 & 0 \\ 0 & -8 & -20 & -5 \\ 2 & 8 & 0 & -5 \end{bmatrix} \qquad \begin{bmatrix} 1 & 0 & 0 & -.833... \\ 0 & 1 & 0 & -.4166... \\ 0 & 0 & 1 & .4166... \end{bmatrix}$$

Six Flags/Magic Mountain

When: Monday, May 26, 2012

Who: All able-bodied senior physics students

How much: Don't worry about it. (Book bill)

Leaving: In AM. Come to school and meet in 203.

Returning: That depends. Let's talk about it.

Assignment: One "applied physics" problem, assigned at beginning of April

Write-up: A "nice" one, word processed, 3-7 pages, with diagrams, illustrations, data tables, graphs, calculations, blurbs, explanations, sources of error, as required.

Six Flags/Magic Mountain

Alex Murphy
AP Physics
4/20/2009

Magic Mountain Write-up

Purpose: The goal of this project is to determine the average launch force on a train on the ride Superman: the Escape.

Materials: The materials used to determine values were very limited because I did not want to carry much around the park; therefore, I collected all of the data using applications on the iPod Touch. I figured I could take two different approaches to the problem so I brought two applications. The first was a better stopwatch that recorded hundredths of seconds. The second was an application that I wanted to try out for fun, called RevLite. This free application supposedly uses the iPod's internal accelerometer to collect instantaneous values for acceleration. I do not expect these results to be reliable (or at all useful) as you are supposed to attach the iPod to the vehicle, which was of course not possible. However, I wanted to compare that data to the data collected with the stop watch.

Sweet!

Procedure: There are two slightly different procedures for each method.

1. Get on the ride, Superman the Escape
2. Try to get a good look at the straight-away of the track (hard to see from anywhere else in the park). Estimate that distance
3. Start either application before/as the ride begins
4. Stop stopwatch at the end of the straight section
5. Stop RevLite at end of ride
6. Record data to be analyzed later
7. Look for a better way to find that length…

Data: From the first ride, I recorded that the time it took to go from the station to the end of the straight piece of track was 7.46 seconds.
I approximated the length of the track to be around two football fields, 200 yards.
Using the RevLite application, the recorded forward and lateral accelerations for the applicable times are attached (with graph). The graph has been included just for fun.

Sean Dembowski
Six Flags Magic Mountain Physics Project
Monday, April 6

Above & beyond the call of duty.... Beautiful work!

Purpose:
Calculate the maximum mechanical energy per kilogram of a train on X2.

Materials:
Stopwatch
Altimeter, or other method to triangulate height
Method of measuring length (could be pacing)

Procedure:
Because the maximum mechanical energy is at the top of the lift hill, that is the point of concern. First, measure the height of the top of the lift hill. This can be done with an electronic altimeter, or by triangulation, though that might be difficult because you can not walk underneath X2.

Next, to get the speed of the train up the lift hill, measure the amount of time it takes for the train to pass a point on the lift hill. Where to start and stop is arbitrary (I used 1st headrest to last headrest) but it must be consistent. Make sure to do at least 3 trials. Next the length is needed. Whatever distance was used to measure the time, this distance must be measured. This can be done by pacing if you can get near the car, otherwise static references and estimation can be used to get the length. With the length and the time, the speed can be calculated.

The rotational energy of the wheels can be found as well, though it turns out to be insignificant. If you need to though, you can estimate the measurements of the wheel and use the density of polyurethane to find the mass and moment of inertia. For this, you will also need the mass of the train, which can be found online or (if you're lucky) with a ride operator.

That's fine!

By the way, the set-up of this write-up is a little different than you asked for. The **Data** section is mostly raw data, and values that required any calculation whatsoever are in the **Calculations** section.

Data:
The problem calls for the maximum mechanical energy, and because the coaster receives no outside work once it reaches the top of the lift hill, the maximum energy is at this highest point (since friction begins to cause energy loss immediately.) Therefore, all relevant measurements at for a train at the top of the lift hill.

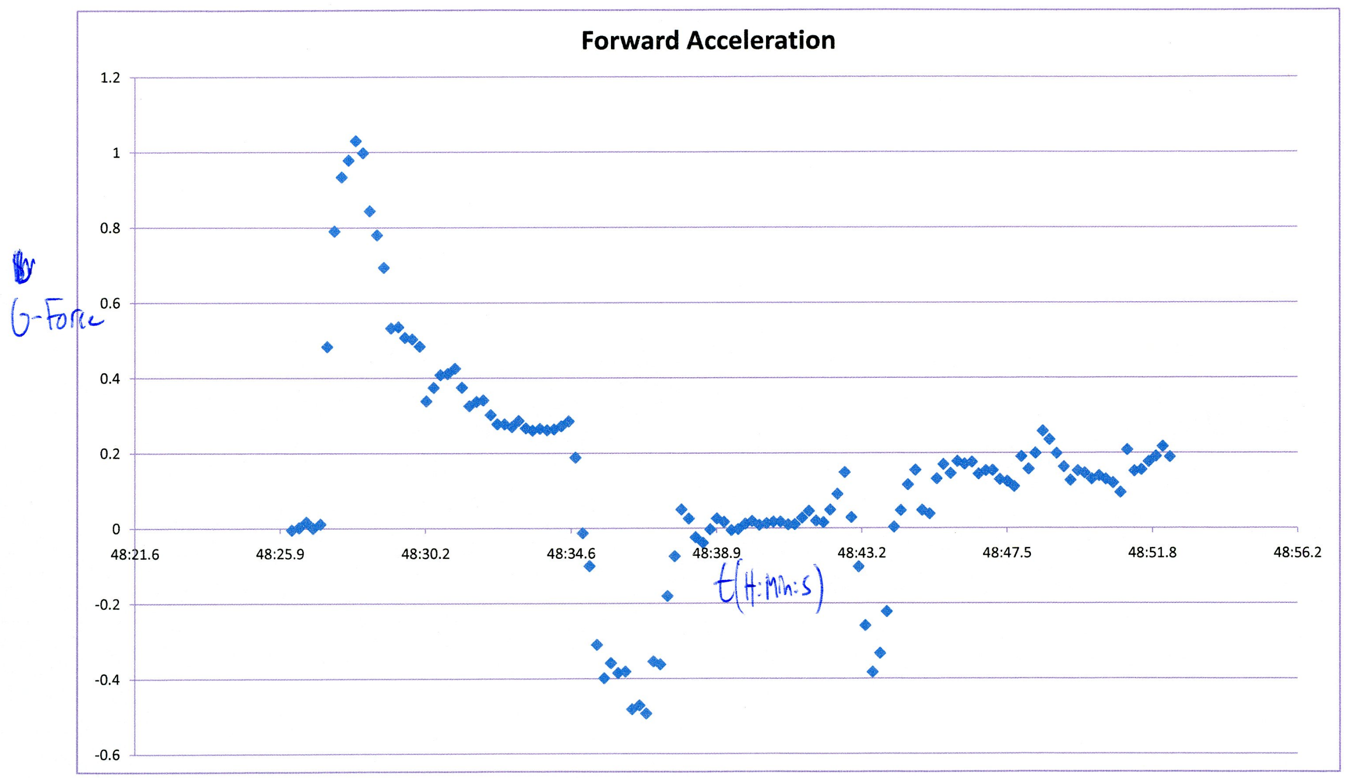
Height: *175ft* (according to sign in X2 line.)
Time: 5 trial average (8.90, 8.95, 9.00, 9.00, 8.90) = *8.95s* (1st headrest – last headrest)
Length: Train = 7 cars, so *6 car-lengths* (headrest to headrest)
1 car-length = 2 track crossbars
2 track crossbar = 4 paces
1 pace = 0.75m

Nicely shown

Six Flags/Magic Mountain

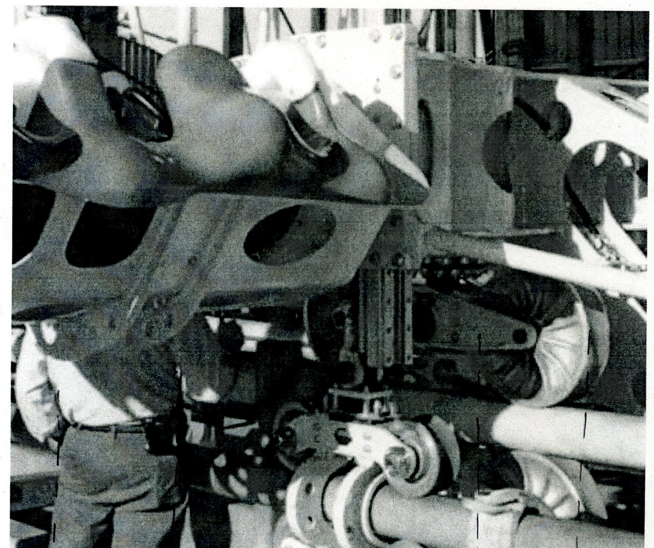
RevLite Data

Time	Forward Accel.
00:00.8	0.011674
00:01.0	0.4836
00:01.3	0.790716
00:01.5	0.934382
00:01.7	0.978835
00:01.9	1.030533
00:02.1	0.998484
00:02.3	0.844494
00:02.5	0.780494
00:02.7	0.694377
00:02.9	0.533099
00:03.2	0.536175
00:03.4	0.508012
00:03.6	0.503739
00:03.8	0.484617
00:04.0	0.33882
00:04.2	0.374861
00:04.4	0.40858
00:04.6	0.411905
00:04.8	0.425772
00:05.0	0.375335
00:05.3	0.326062
00:05.5	0.337624
00:05.7	0.341349
00:05.9	0.302229
00:06.1	0.277803
00:06.3	0.277395
00:06.5	0.270242
00:06.7	0.286619
00:07.0	0.266813
00:07.2	0.260497
00:07.4	0.265577
00:07.6	0.261807
00:07.8	0.263765
00:08.0	0.271941
00:08.2	0.284948



Six Flags/Magic Mountain

Fig. 1



1 backwidth

a little less than 1 backwidth, but when looking head-on, probably ~ 1 back width.

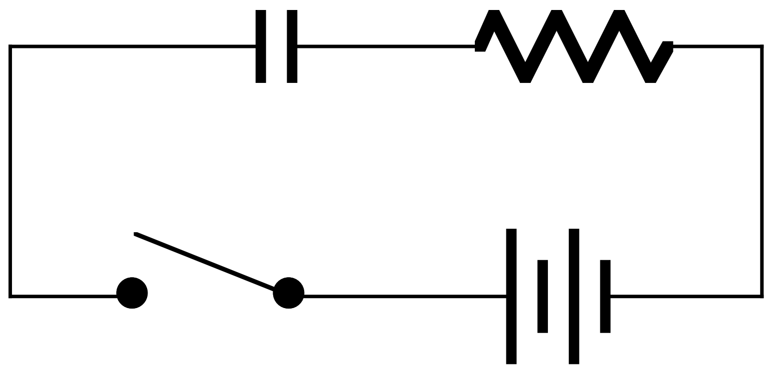
Therefore, radius of large wheel (R_L) ≈ $\frac{1}{2}$ backwidth.
On me, backwidth = 12 inches, so

$R_L \approx 6$ in

Series & Parallel Activity

Examine the series and parallel circuits assembled in class... and don't touch the wires.

RC Circuits - Charge



$$V_o - V_{capacitor} - V_{resistor} = 0$$

$$V_o - \frac{q_{plate}}{C} - I_{inst}R = 0$$

$$V_o - \frac{q_{plate}}{C} - \frac{dq}{dt}R = 0$$

$$\frac{dq}{dt} = \frac{V_o}{R} - \frac{q}{RC}$$

$$\frac{dq}{dt} = \frac{V_o}{R} - \frac{q}{RC}$$

$$\frac{dq}{dt} = \left(\frac{V_oC}{RC} - \frac{q}{RC}\right) = \frac{V_oC - q}{RC}$$

$$\frac{dq}{q - V_oC} = \frac{-1}{RC}dt$$

$$\int_0^q \frac{dq}{q - V_oC} = \int_0^t \frac{-1}{RC}dt$$

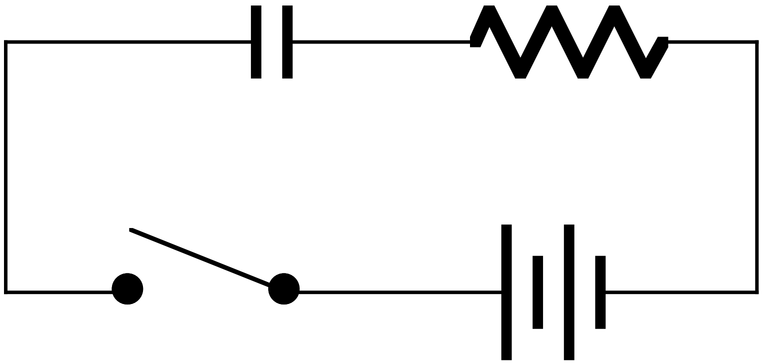
$$\ln(q - V_oC)\Big|_0^q = \frac{-t}{RC}$$

$$\ln\left(\frac{q - V_oC}{-V_oC}\right) = \frac{-t}{RC}$$

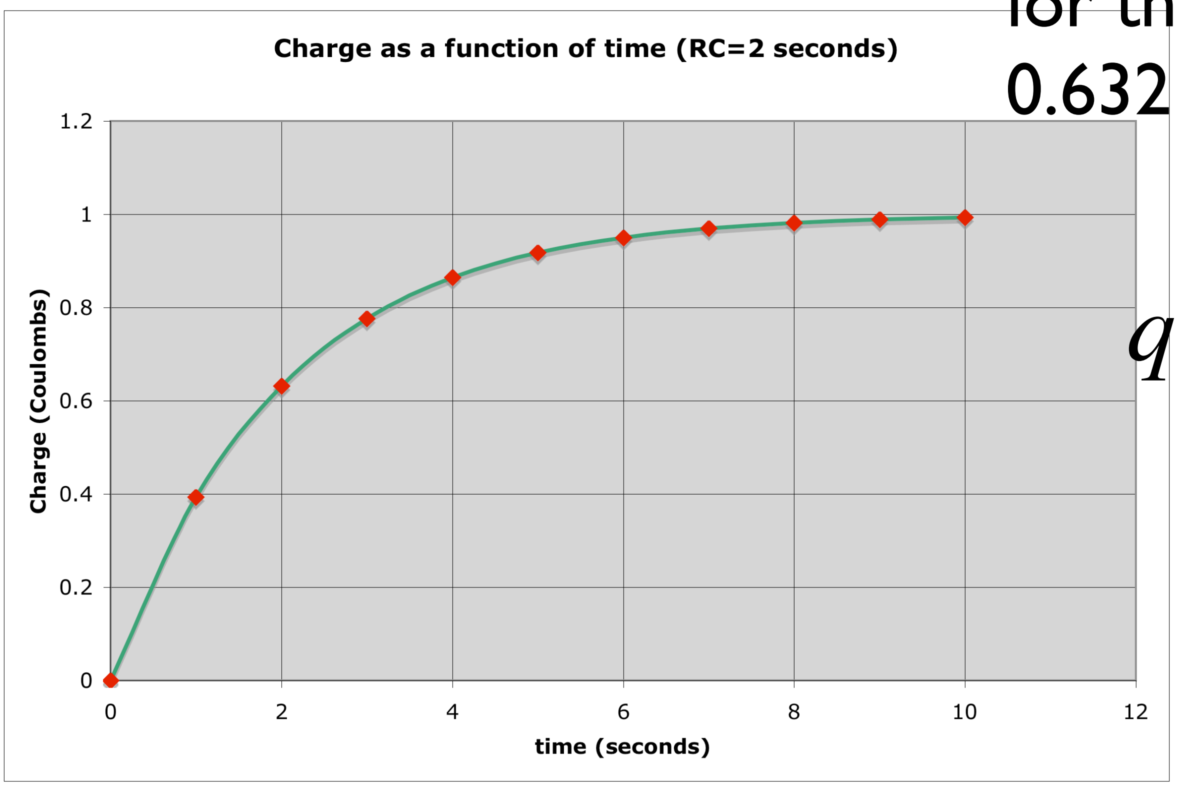
$$q(t) = CV_o[1 - e^{-t/RC}]$$

$$q(t) = Q[1 - e^{-t/RC}]$$

RC Circuits - Charging

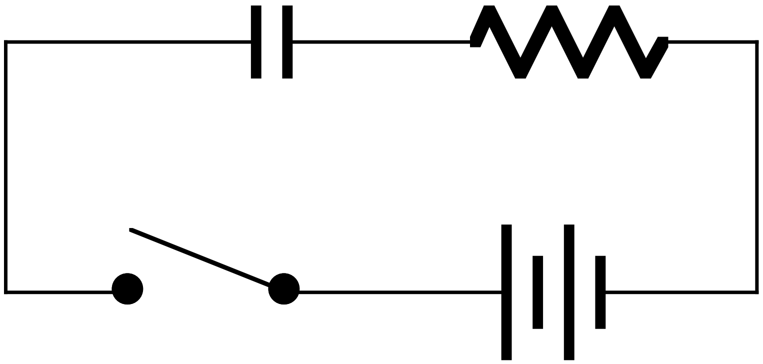


The quantity τ = RC is called the "time constant" for the circuit, and (in this circuit) represents the amount of time (in seconds) for the charge to reach 0.632 of its total value.

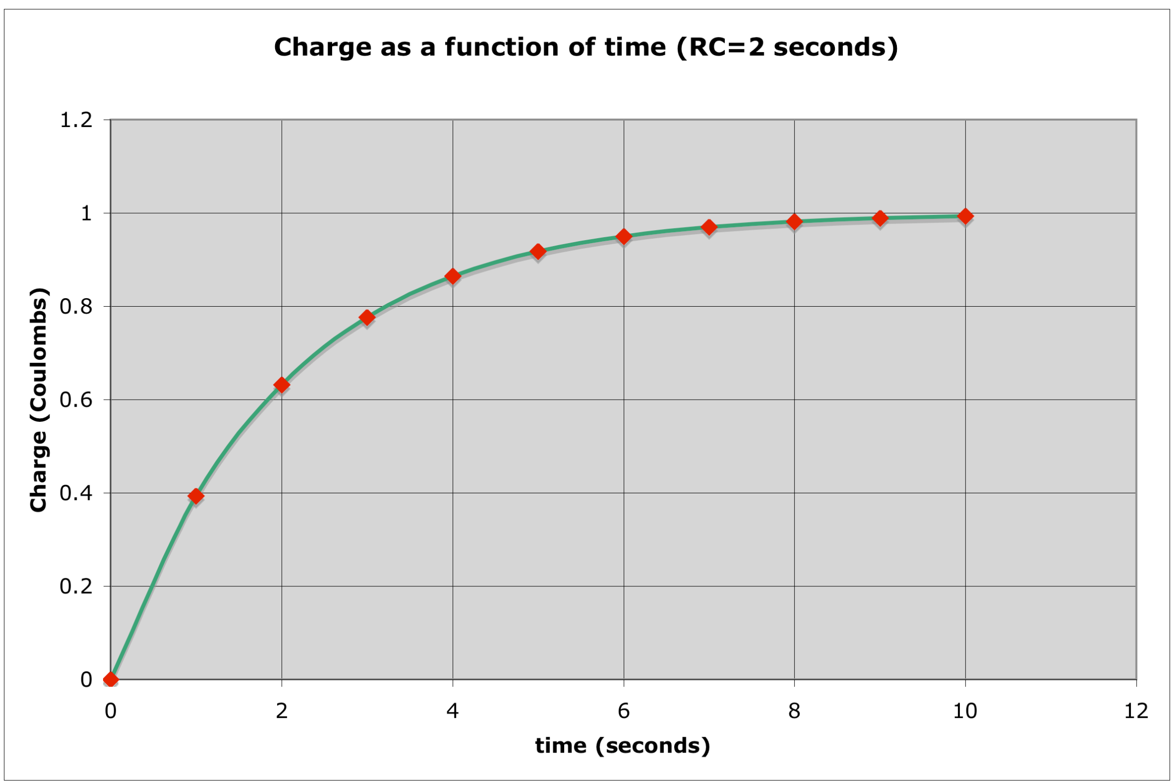


$$q(t) = Q(1 - e^{-t/RC})$$

RC Circuits - Discharging

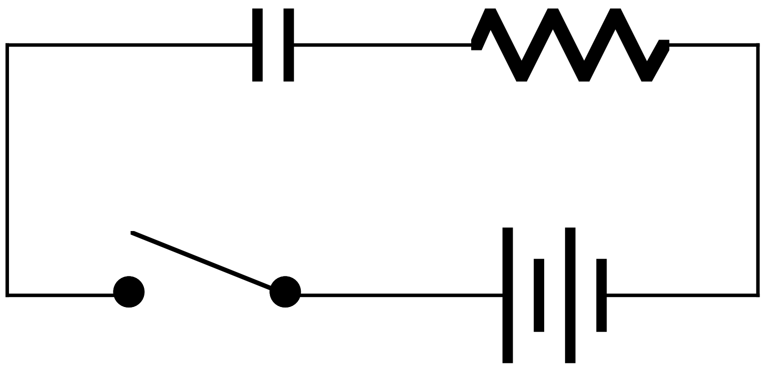


What is the function for a *discharging* capacitor? What does τ = RC represent for a discharging capacitor?



$$q(t) = Q(e^{-t/RC})$$

RC Circuits - Current



$$q(t) = Q[1 - e^{-t/RC}]$$

$$I = \frac{dq}{dt}$$

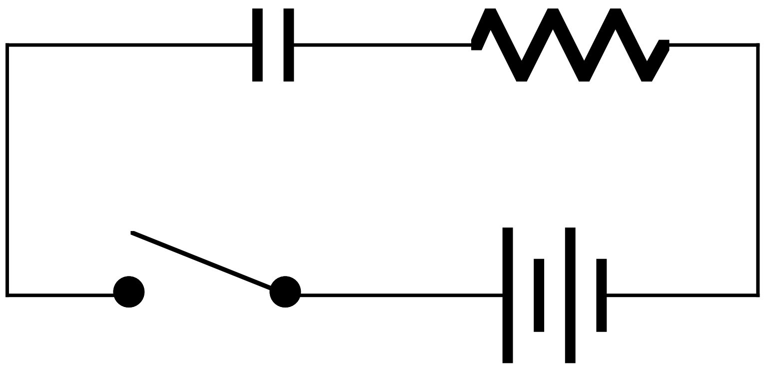
$$I = \frac{d}{dt}(Q[1 - e^{-t/RC}])$$

$$I = Q(\frac{d}{dt}1 - e^{-t/RC})$$

$$I = Q(\frac{-1}{RC})(-e^{-t/RC})$$

$$I(t) = \frac{V_o}{R}e^{-t/RC} \qquad I(t) = I_o e^{-t/RC}$$

RC Circuits - Current



What is the function for current of a *discharging* capacitor?

$$I(t) = -\frac{Q}{RC} e^{-t/RC}$$

Example 5

An RC circuit has a 6V battery, a 200μF capacitor, and a 5000 Ω resistor.

a. Draw a picture of the circuit.

b. What is the flow of current through the circuit I_o just after the switch is thrown?

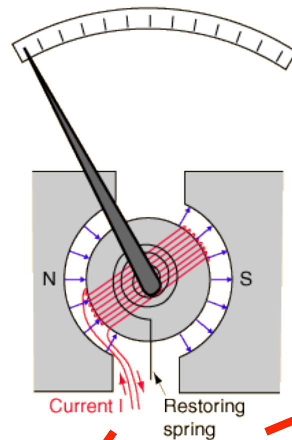
c. What is the time constant for the circuit?

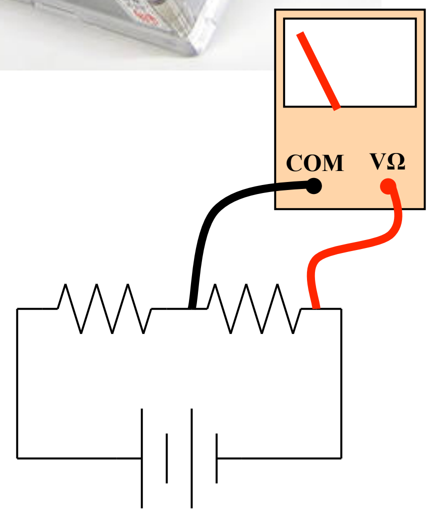
d. How much current is flowing in the circuit 5 seconds after the switch has been thrown?

e. Sketch a graph of the circuit's current vs. time, using at least 3 data points that you calculate.

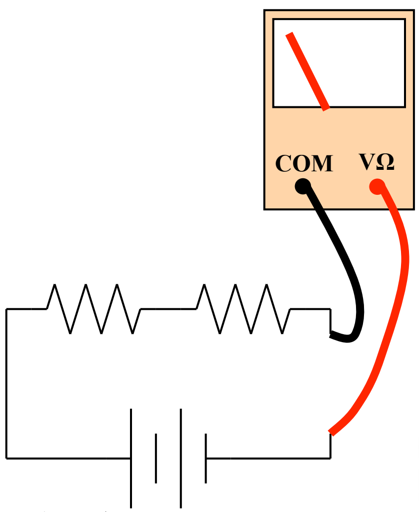
Galvanometers

A *galvanometer* is a type of meter that, in conjunction with appropriate resistors, will allow one to measure current (as an *ammeter*) and electric potential difference (as a *voltmeter*).





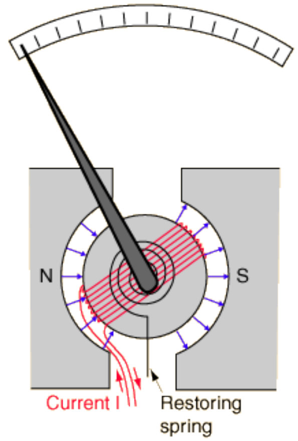
Ideal voltmeters have high resistance.

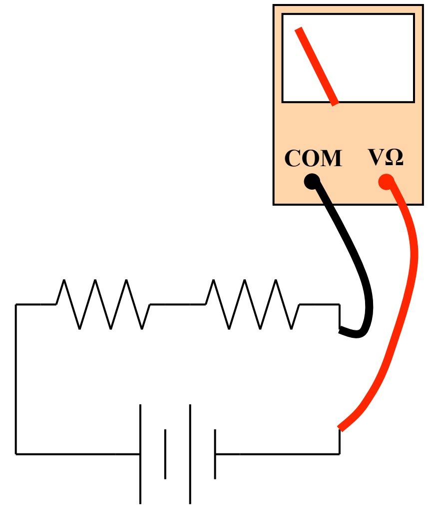


Ideal ammeters have low resistance.

Mr. White's Ammeters

The galvanometer all by itself has some resistance (say 20 Ω), and deflects fully across the face of the meter at some current value (industry standard is 0.0005A). How can we alter this galvanometer so that it will be able to measure currents (deflect fully) up to 0.100A?



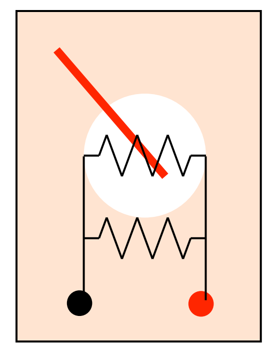


$$V_{\text{full deflection}} = IR = (0.0005\,A)(100\Omega) = .050V$$

$$R_{\text{needed}} = \frac{V}{I_{\text{new}}} = \frac{.050V}{0.10\,A} = .50\Omega$$

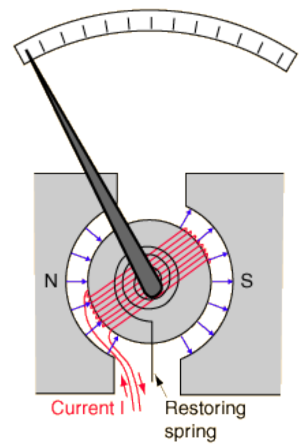
$$\frac{1}{100} + \frac{1}{R_{\text{shunt}}} = \frac{1}{.5}$$

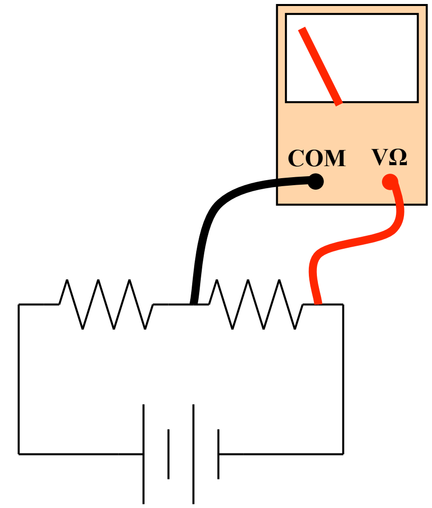
$$R_{\text{shunt}} = .503\ \Omega$$



Voltmeters

The galvanometer all by itself has some resistance (say 100Ω), and deflects fully across the face of the meter at some potential value (say 0.10V). How can we alter this galvanometer so that it will be able to measure currents (deflect fully) up to 10V?





$$V = IR = (0.001A)(100\Omega) = 0.10V$$

$$R_{needed} = \frac{V_{new}}{I} = \frac{10V}{0.001A} = 10{,}000\Omega$$

$$100 + R = 10{,}000\Omega$$

$$R = 9900\Omega$$